3D Scanning Documentation of Two Different Objects – the King's Chinese Cabinet in Wilanow Palace Museum and a Roman Gravestone from Archeological Excavations in Moesia Inferior as a Part of Multidisciplinary Research

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Abstract— In the presented article two examples of use of high resolution 3D scanning for documentation of cultural heritage objects will be shown. Comparison of two entirely different objects, made of different materials (polychromatic wood and porous limestone) shows versatility of this scanning technology, which will revolutionize heritage documentation. Important aspect is the complexity of specially created environment for data processing in which massive data sets (up to 20 billion of measurement points) can be automatically processed and visualized.

Keywords- 3D shape measurement, structured light, cultural heritage 3D digitization, conservation documentation

I. INTRODUCTION

In the last few decades the research methods applied to cultural heritage objects analysis have been rapidly developed. More and more sophisticated technology is used for chemical composition analysis of objects. On the other hand visual documentation techniques haven't advanced significantly. The biggest breakthrough was gradual digitization of archiving methods. Replacing older methods with 2D digital image representation was becoming more popular and today we can regard them as entirely predominant with respect to analog techniques. A meaningful sign is the fall of KODAK – a pioneer in the field of traditional photographic technology. However, gathering an increasing amount of information about objects of interest and ordering it using database systems creates more challenges. Attempts to analyze cultural heritage objects in a multilateral way lead to revealing mutual relations, but without appropriate visualization the gathered information can only be used separately and drawing synthetic conclusions is extremely difficult.

One solution is to use systems based on the GIS (geographical information system) philosophy. Such applications are known from e.g. frequent attempts to map facades of antique buildings in order to track degradation processes. This philosophy however is severely limited due to the fact that the current stage of development of such systems is too low to successfully visualize large datasets of three-dimensional data in real-time. This impedes managing the data in the case of objects with more complicated geometry, which require visualization in a non-processed and non-simplified form. The development of GIS software in time will probably overcome these limitations, but currently other solutions have to be developed.

The dissonance between more and more complicated physicochemical diagnostics and rather simple graphical visualization methods is clear. Presenting incredibly complicated analytical data in very conventional, schematic visualizations is common practice. Popularization of documentation based on precise 3D measurement [1,2] makes it possible to change this situation, provided that the non-simplified and non-processed measurement data could be visualized and analyzed in real-time.

For a few years now the Warsaw University of Technology (WUT) Mechatronics Faculty in cooperation with Wilanow Palace Museum has been developing technology for documenting works of art based on precise three-dimensional measurements. Structured light illumination scanning was chosen as the registering technique [3]. In the presented article two examples of use of high resolution 3D scan for documentation of cultural heritage objects are presented. Comparison of two entirely different objects, made of

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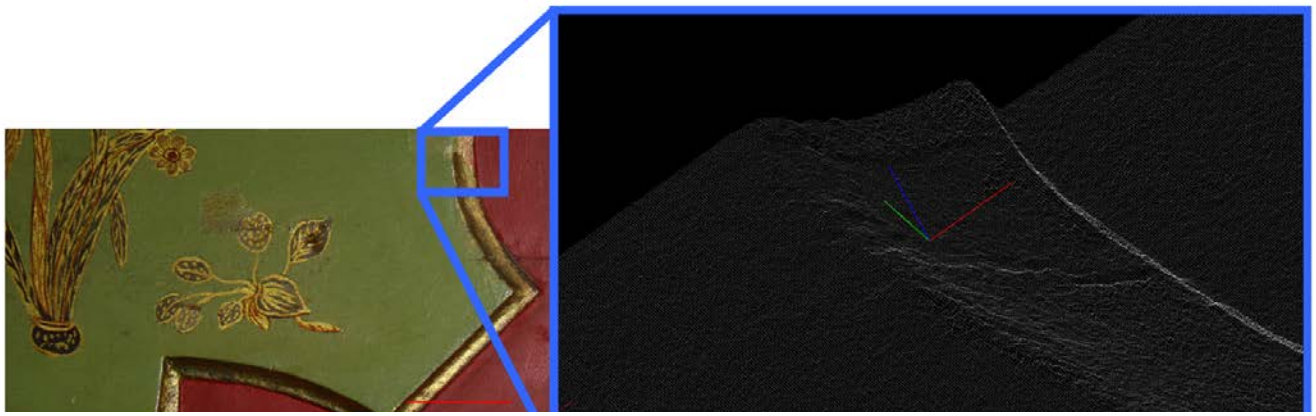

Figure. 1 Exemplary cloud of points representing paintings layers on the wood in King's Chinese Cabinet together with visualization of zoomed (x, y, z) points.

different materials (polychromed wood and porous limestone) shows the versatility of the scanning technology used, which has the potential to revolutionize the process of creation of heritage documentation. An important aspect is the complexity of software environment created for data processing, in which massive data sets (up to 20 billion measurement points) can be automatically processed and visualized.

The 3D measurement technique used in this study is structured light illumination (SLI), which employs the temporal phase shifting method combined with hierarchical phase unwrapping [4]. The typical measurement sampling density is ranging from 10µm up to 1mm with use a digital camera with typical resolution up to 20MPix. The measurement system can be adaptively calibrated to the required volume thus different sampling densities can be achieved.

Data acquisition is supported by automated manipulation of a measurement head by a robot arm and data processing is automated by 3DMADMAC environment [5]. This environment supports data filtering, view integration and processing. The environment for real-time massive data visualization of final point based model is also developed at WUT to give the whole system a high level of maturity.

II. Documentation and Analysis of King's Chinese Cabinet

The first analyzed object is the King's Chinese Cabinet from the Royal Palace in Wilanów. This unique example of interior decorative art was made using a European lacquer technique in XVIII century and it is attributed to the famous 18th century craftsman Martin Schnell and his workshop [7]. After leasing Wilanów to King Augustus II the Strong, artists from the court of Saxony were working on the new appearance of the royal apartments. A few years ago a research project was introduced to assess the condition of polychromy and to identify the technique and technology of the decoration in the Cabinet [9]. Stratigraphic cross-sections of paint samples were analyzed with SEM-EDS technique. The results were combined with observations of pigments from particular painting layers in reflected and transmitted light, ultraviolet fluorescence microscopy and completed with additional microchemical tests. Identification of dyes was conducted by means of UV, VIS and FTIR absorption spectrometer and HPLC. For identification of binding media FTIR and GC/MS were used .

The results of both traditional and advanced technology analysis techniques were compared with other investigations of European lacquer works of art, especially those attributed to Martin Schnell [8].

The conducted research has revealed unexpected results. Under green parts of wooden panelling that were certainly not original, blue- and pink-like colours were discovered. The original color scheme of the King's Chinese Cabinet was much different from its state in 2009. A very difficult decision to remove secondary coatings revealing the interior's original character has been made.

Before carrying out conservation and restoration works, entire surfaces of wooden panels and painted decorations (more than 90 square meters) were scanned with the structured light 3D scanning technology. We used a measurement sampling density of 0.1mm (Fig. 1) with uncertainty of 50µm. During the documentation process, which took 2 months, approximately 1200 directional scans have been done. Each of them consisted of 8-15 millions of measurement points. With the use of the 3DMADMAC environment, all this data has been automatically filtered and integrated in one model, with very limited human guidance (Fig. 2).

Three-dimensional documentation of the whole Cabinet (decorations on all four walls and the ceiling painting were measured) created a new level of quality for working with documentation data. This documentation technique replaced the high-resolution orthophotoplan method with dozens of photographs of details taken with varying illumination. It has to be outlined that for conservators working in the project the perception of such a scan is much easier and more intuitive than using traditionally prepared schemes with tens of attached photographs. A single cloud of points contains comprehensive information about the appearance of the work

Figure. 3 The King's Chinese Cabinet – a part of eastern wall (visualization of raw measurement data with virtual light source)

of art, not only allowing for precise dimensioning or extraction of sections, but also for the analysis of aesthetical features of the object. This highly accurate method of documentation can be used for saving the preservation state of antique's surface as well as for "managing" the data concerning works planned for the object. Possibility of calculation of real surface area of regions with the same color (e.g. gilts on decoration elements of complex shape) saves time and reduces errors connected with estimating the regions difficult to measure with traditional methods.

An accurate 3D model gives the ability to mark the locations of microsamples used for identification very precisely, which has fundamental significance in the correct interpretation of results. With constantly increasing amounts of microchemical and non-destructive examinations the map of measurements prepared using a 2D photograph or an orthophotoplan ceases to be legible.

Two years ago in the course of conservation works all the elements of decorations were dismantled. Until December 2011 the elements were collected from external conservation workshops and were mounted back on the walls of the Cabinet (Fig. 3).

Figure. 2 View of a wall fragment after conservation in 2012.

The documentation created by us is now the only evidence of the appearance of the room before 2010. The 3D documentation, orthophotoplans and traditional pictures in VIS and UV light allowed full documentation of the state of preservation of the whole room.

III. Documentation and Analysis of the Roman Gravestone

The second measured object was a part of Roman gravestone from one of the ancient cities in the province of Moesia Inferior [10]. Moesia Inferior was one of the most important Roman provinces in the Balkans in the 2nd and 3rd century AD. The gravestone (inv. No 96/93w) 1.4 m high and 0.9 m wide was adorned with complex carved decoration and Latin inscription in seven verses. Among the decoration elements used there are many images of birds recognized by the ornithologists [6]. This gravestone, extremely complicated to analyze, remains in Bulgaria in accordance with the international law.

The 3D documentation prepared for the object (sampling density used was also equal to 0.1mm) enabled sharing images of the gravestone for wide scientific and educational use. Over the course of 4 days of scanning and data processing, the final model has been created (Fig. 4) in the form of triangle mesh from 136 directional measurements.

Preparation of high quality descriptions of techniques used during the creation of the works of art was difficult and required– contacting experts for the documented object. This type of analysis is not possible by means of classical visual documentation (drawings and photographs). The proposed method of documentation allows to analyze surface shape and appearance from different angles and with controlled direction of illumination. Thanks to shape analysis it is possible to calculate the width and type of the tooth chisel used, as well as the characteristic path of tool marks on the surface of the limestone.

The marks of tools used to shape the block of stone are one of the most valuable sources of knowledge for persons involved in the analysis of technologies used to produce a particular work of art. Evaluation of marks of this type may be utilized to identify certain types of tools used. It permits the estimation of the skill level of the artisan. The delicacy of those marks makes them very difficult to document by means of traditional methods, causing description of the technology used for a particular object to be impossible without physical contact of the researcher with the artifact.

The most important feature is the ability to observe the original technique of creation of details on the sculpture, as well as how the tool (usually a chisel) was "led" on the surface of the material. The manner of holding the chisel between subsequent strokes corresponds to the type of marks left on the

Fig. 4 Three-dimensional documentation of the surface of stele presented in the form of a triangle mesh.

surface of the stone. Obtaining a textured surface treated with a tooth chisel with grooves of identical depth and ordered character of the surface requires more ability from the mason.

IV. SUMMARY

The presented three-dimensional documentation, carried out with the same spatial resolution concerns two entirely different objects. One of them has the area of more than 90 m^2, while the other only 1,26 m^2. In the case of the Chinese Cabinet the documentation was prepared with the objective to assist in complicated identification investigations, as well as to preserve a record of the antique's contemporary appearance, which was severely modified due to conservation works. In the case of the roman sepulchral stele the point was to capture the characteristic features of the surface of stone and verification of the ornithological investigations of the images of birds. Fully automated scanning and processing of the sepulchral stone (136 measurements, with the number of measurement points reaching 615 million) allowed to generate a triangle mesh of approximately 1 million triangles in less than one week. The works carried out with the Chinese Cabinet resulted in a much longer time and larger dataset. In this case it turned out that the attempts to create triangle meshes are ineffective and lead to massive data simplification and introduce an undesired subjective effect in the documentation. Due to this fact, for working with such large datasets it is more practical to use the representation in the form of a raw cloud of points. Development of specialized software allows to use such dense clouds of points to capture all the documentation requirements mentioned in this paper.

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